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Cadaveric assessment of a new guidewire insertion device for volar percutaneous fixation of nondisplaced scaphoid fracture

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ABSTRACT

Purpose: Volar percutaneous screw fixation (PSF) of acute nondisplaced scaphoid waist fractures allows early mobilisation of the wrist and a faster return to work than prolonged cast immobilisation. Usually, placement of the wire which guides the definitive canulated screw is performed with the hand held. Nevertheless, correct placement of this wire is technically difficult. We designed a guidewire insertion device (GID) to facilitate this placement.

Methods: We compared the hand held technique with the technique using the GID in a cadaveric study. The hand held technique was performed on 16 scaphoids and the GID was used in 16 other scaphoids. The four participating surgeons were divided into two groups: two experienced surgeons and two inexperienced surgeons.

Results: The GID significantly decreased procedure duration ($P < 0.001$), number of attempts to place the wire ($P < 0.001$), and number of image-intensifier shots ($P < 0.001$). With both techniques, experienced surgeons were significantly faster ($P = 0.0083$) and required significantly fewer attempts ($P = 0.043$) than inexperienced surgeons. Using the GID, the procedure duration ($P = 0.0039$) and the number of image-intensifier shots ($P < 0.001$) decreased more with inexperienced surgeons than with experienced surgeons. As for the number of attempts, there was no statistical difference between the two groups ($P = 0.32$).

Conclusions: The GID decreased the time and radiation exposure needed to achieve correct volar percutaneous wire placement in the scaphoid, compared to the conventional hand held technique. Easier wire placement may lead surgeons to use PSF instead of prolonged cast immobilisation for treating nondisplaced scaphoid fractures.

Introduction

The scaphoid is the most frequently fractured carpal bone and the majority of such fractures occur at the waist.[15,28] The annual incidence of scaphoid fractures was estimated at about 43/100,000 overall[18] and was markedly higher in men (38/100,000) than in women (8/100,000).[20] Scaphoid fractures are managed by physicians working in several specialties, including emergency medicine, plastic surgery, and orthopaedic surgeons.[3,9,23,26] Scaphoid fractures have a major socioeconomic impact, as they heal slowly and result in nonunion in about 12% cases,[11] leading to prolonged work disability.[6,31,32]

Acute nondisplaced scaphoid waist fractures are currently treated with either cast immobilisation or percutaneous screw fixation (PSF). PSF allows early mobilisation of both the wrist and the elbow and a faster return to work, with comparable healing times and rates but a lower overall cost, compared to cast immobilisation.[2,4,10,15,19,24,31] The first step of PSF is the insertion of a guidewire, which is then used to guide the definitive cannulated screw. Correct placement of this guidewire is crucial to the success of the procedure but remains difficult to achieve, for several reasons: the three-dimensional shape of the scaphoid is very complex and it is a very small bone.[5,7,8] Therefore, using two-dimensional images for guidewire positioning offers limited accuracy. However, considerable accuracy is required, since the bone is small and incorrect guidewire placement increases the risk of nonunion.[1] Although both anteroposterior and lateral radiographs are used to position the guidewire, the surgeon can see only one view at a time on the image intensifier. Adjusting guidewire position in one plane without modifying its position in the other plane is extremely difficult. Repeated adjustments are required to

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achieve correct placement in both planes, which increases both the duration of the procedure and the radiation dose received by the patient and surgeon. Methods for facilitating screw placement have been developed. Herbert et al. designed a jig for screw insertion during open surgery.[16] A cadaver study suggested that fluoroscopic navigation may help to achieve correct guidewire placement.[21]

The first author of this manuscript designed an original guide insertion device (GID) that allows adjustment of guidewire position on one view (anteroposterior or lateral) without modifying the position on the other view. The aim of this cadaver study was to assess the impact of using GID on the easiness, duration and success of completing the procedure.

Materials and methods

We used 32 scaphoids (16 left and 16 right) from 16 fresh frozen cadavers. Each wrist was examined visually and fluoroscopically for any evidence of trauma or surgery. Wrists showing such evidence were to be excluded from the study.

Four surgeons with different levels of expertise in hand surgery participated in the study: two were orthopaedic surgery residents who had no experience with scaphoid PSF and two were senior hand surgeons who had considerable experience with scaphoid PSF. Each surgeon performed the procedure on eight scaphoids, using the GID for two left and two right scaphoids and the hand held technique for two left and two right scaphoids. Scaphoid allocation to the guidewire device or hand held technique was randomised and stratified on surgeon experience and side.

The GID was made of aluminum. Manufacturing plans were created using 3DSMax® software (Autodesk, San Rafael, CA). The device was composed of a horizontal base carrying two parallel vertical blades separated by a 5-mm space (Fig. 1). A cylindrical component 5 mm in diameter moved freely between the two blades. The cylinder was cannulated to allow the passage of guidewires 1 mm in diameter. This cylinder was called "reducer" because it allowed to reduce the diameter of the wire's pathway from 5 mm (the space between the two blades) to 1 mm (the diameter of the guidewire).

For both the hand held technique and the technique using the GID, the upper limb was placed on an armboard. A Siremobil® (Siemens, Munich, Germany) image intensifier set on zoom mode was used. A 5-mm skin incision was made over the trapezium, and the soft tissues were dissected down to the bone. A wire 1 mm in diameter was put on a drill and the tip of the wire was inserted into the tubercle of the scaphoid. The entry point was that described by Menapace et al.[25] The wire was pushed into the scaphoid under image-intensifier guidance, using anteroposterior and lateral views, the goal being placing the guidewire in the centre of the proximal pole without exiting the scaphoid. During the procedure, the wire position was assessed on the image-intensifier views by both experienced surgeons and one inexperienced surgeon. If at least one of the experienced surgeons determined that the guidewire position was incorrect, the guidewire was removed and a new attempt at correct placement was made. The procedure was stopped when the two experienced surgeons judged that guidewire position was correct (Fig. 2). For each procedure, the following data were recorded on a form: experience of the surgeon (inexperienced/experienced), side of the wrist, duration of the procedure, number of wire-placement attempts, and number of image-intensifier shots.

Hand held technique

The C-arm of the image intensifier was positioned vertically. The wrist was placed under the image-intensifier beam and could be moved freely in pronosupination and flexion-extension to obtain anteroposterior, oblique and lateral views of the scaphoid. The guidewire was guided by hand and pushed with the drill into the scaphoid.

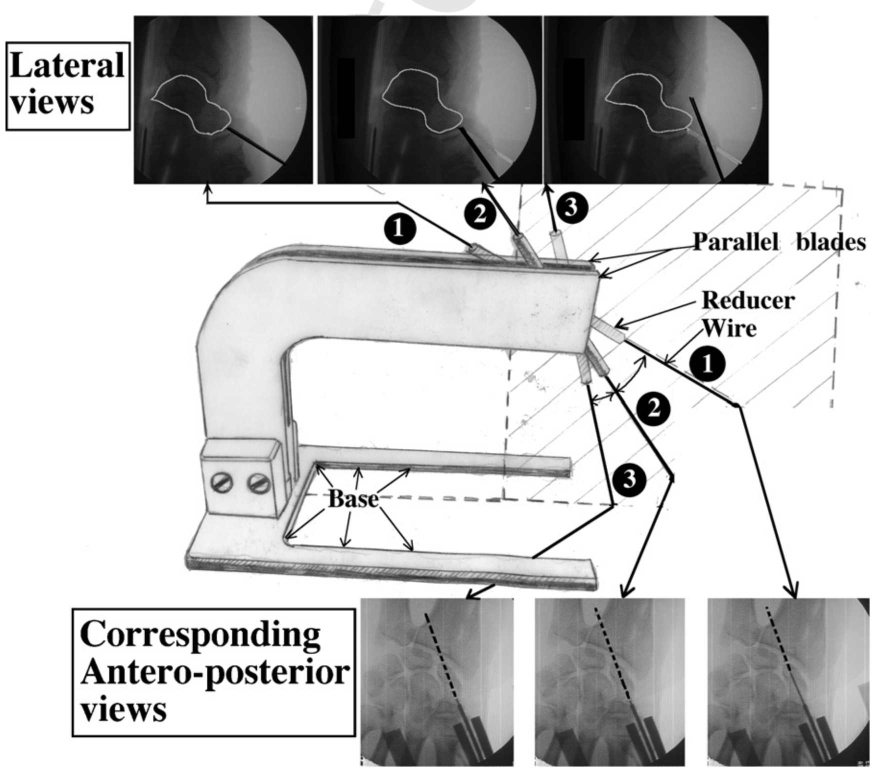

Fig. 1. Description of the GID. The wire is inside of the cylindric reducer which is freely mobilisable between both the blades of the guidewire device. While the wire is mobilised between the blades, its direction on the lateral views changes while it remains the same on the anteroposterior views.

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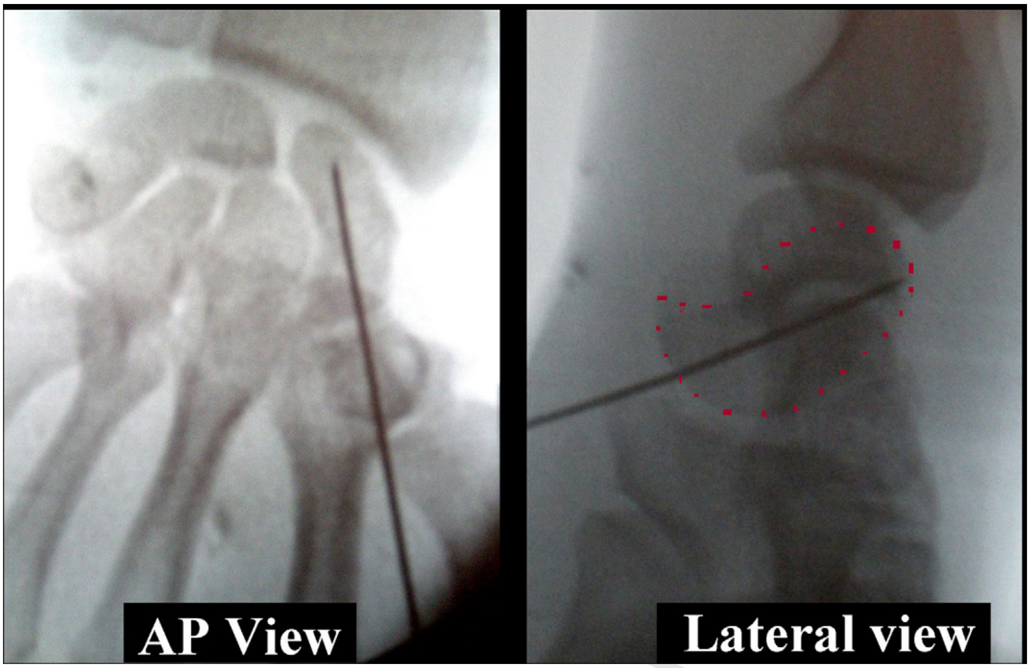

Fig. 2. An example of a guidewire correctly placed into the scaphoid.

Technique with the GID (Figs. 3 and 4)

The wrist was placed on the armboard under the image-intensifier beam and locked in supination and extension using a radiotransparent wrist-stabilising device (Chirobloc®, Arex, Palaiseau, France). The wrist-stabilising device was attached to the armboard with adhesive bands. The C-arm was free to rotate from the vertical position to the horizontal position, which was

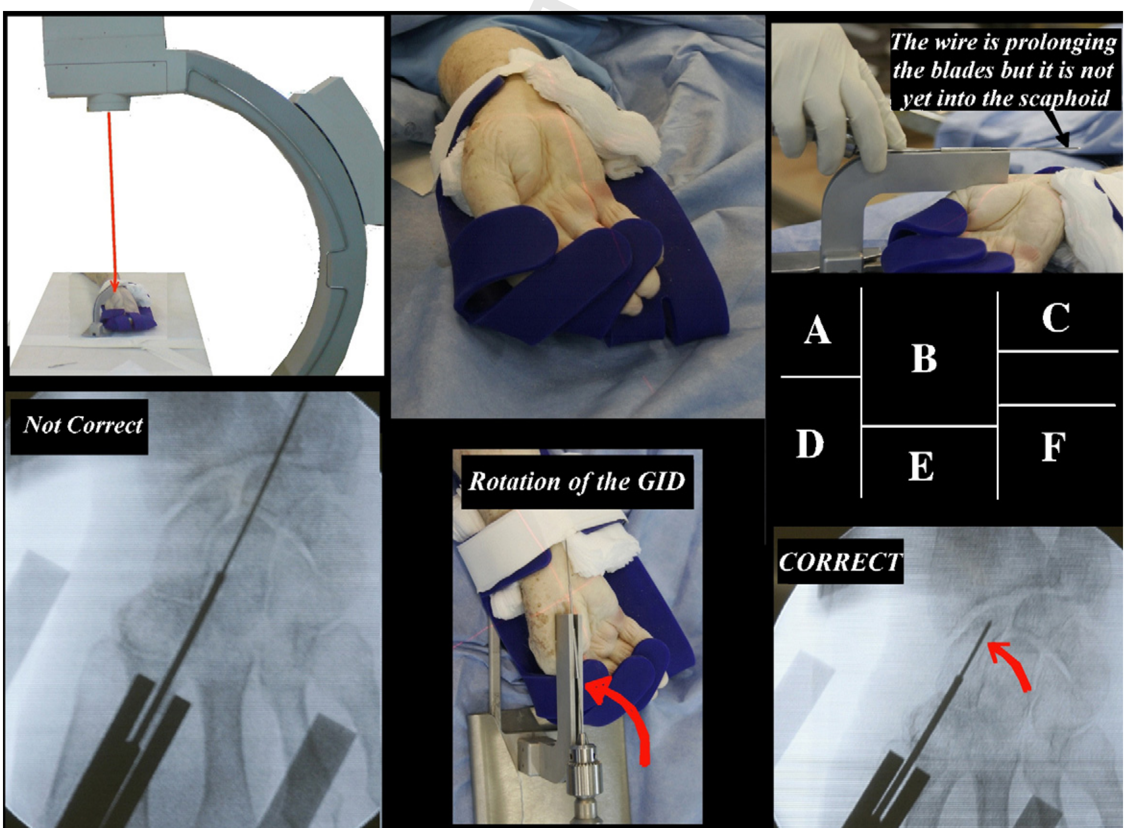

Fig. 3. The C-arm is vertical (A) and the wrist is immobilised with the radiotransparent handlead (B). At this time, the wire is out of the wrist, prolonging the blades of the GID (C). The C-arm of the image intensifier is vertical in order to obtain an anteroposterior view of the scaphoid and radioscopic projection of the guidewire on the scaphoid (A and D). The ideal direction is obtained by rotating the GID horizontally on the armboard (E). When the direction is considered as correct on the anteroposterior view (F), the GID and the specimen's hand are left in the same position.

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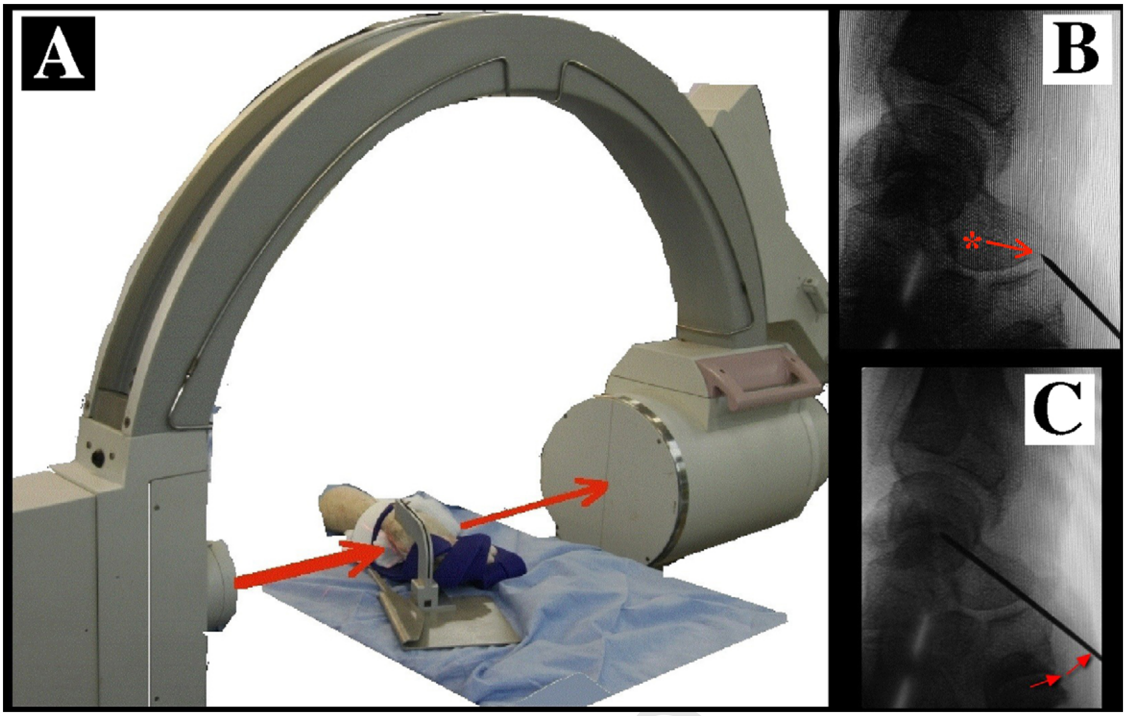

Fig. 4. The C-arm of the image intensifier is rotated horizontally (A) in order to obtain a lateral view of the scaphoid. The operator can move the guidewire vertically between the blades of the GID in order to find firstly the ideal entry point on the scaphoid distal pole (B) and secondly the optimal direction to reach the proximal pole (C). During all this step, the operator can move the wire between the blades of the GID without assessing the direction on the anteroposterior view which is locked by the GID. Thus, he can fully concentrate on the sagittal placement of the wire.

used to obtain anteroposterior and lateral views of the wrist, respectively. The procedure started with the C-arm of the image intensifier vertical to obtain anteroposterior views. The wire was introduced into the reducer, which was then inserted between the two blades of the guidewire device. The GID was moved horizontally until the guidewire projected over the scaphoid was in the desired position on the anteroposterior view. The wrist-stabilising device remained immobile on the armboard. Then, the C-arm was rotated 90° to obtain a lateral view without changing the position of the GID. On the lateral view, the wire was moved vertically between the two blades of the GID until its tip projected on the base of the scaphoid tubercle. The wire was then aimed at the centre of the proximal pole and pushed into the scaphoid with the drill. Finally, the C-arm was rotated back to the anteroposterior view to assess wire position.

Assessment of wire position in the scaphoid (Fig. 5)

Each scaphoid was extracted by open dissection, leaving the wire into the bone. Computed tomography (CT) of each scaphoid

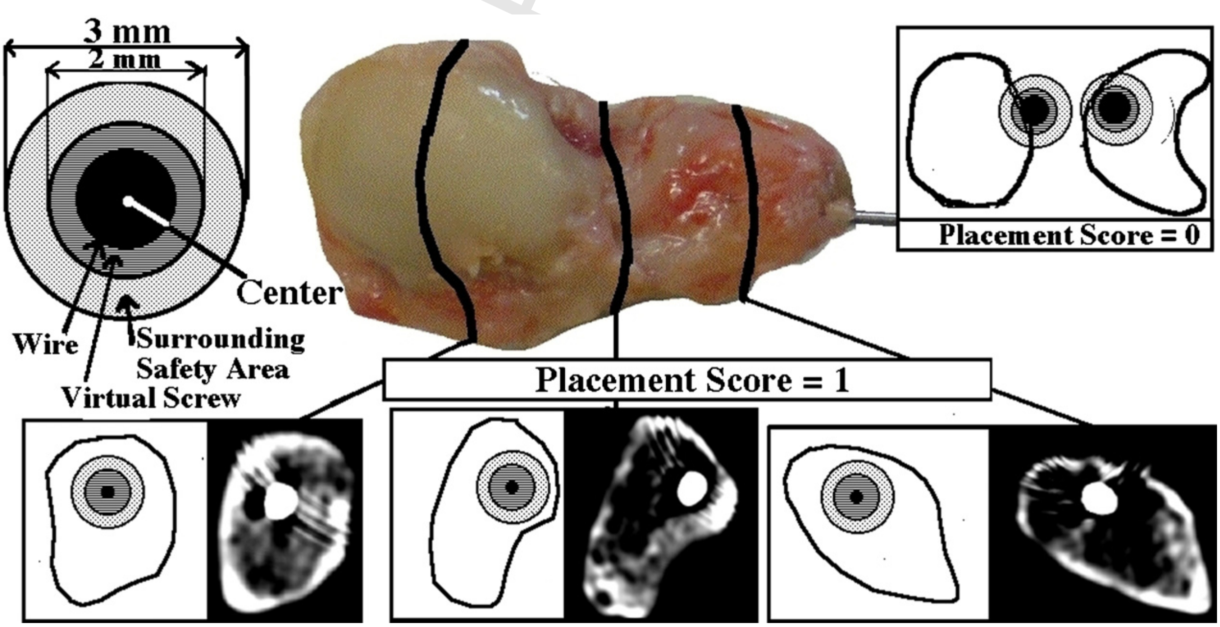

Fig. 5. Each scaphoid was extracted with the wire inside and was divided in three parts. A segmentary placement score (SPS) was calculated at each level. The global placement score (GPS) was the sum of the three SPS.

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Table 1

Wrist	Specimen	Side	Surgeon	Technique	Time	Number of attempts	Number of image-intensifier shots	Distal SPS	Middle SPS	Proximal SPS	GPS
1	1	R	1	Hand held	723	8	31	1	0 (less than 2 mm with the scapho-capital joint)	1	2
2		L	1	GID	345	1	7	1	1	1	3
3	2	R	1	GID	306	1	9	1	1	1	3
4		L	1	Hand held	750	9	38	1	1	1	2
5	3	R	1	Hand held	624	5	22	1	1	0 (out of the radial surface of the scaphoid)	2
6		L	1	GID	282	1	6	1	1	1	3
7	4	R	1	GID	321	1	7	1	1	1	3
8		L	1	Hand held	587	6	30	1	1	1	3
9	5	R	2	Hand held	622	7	37	1	1	1	3
10		L	2	GID	362	1	5	1	0 (less than 2 mm with the scapho-capital joint)	1	2
11	6	R	2	GID	513	2	14	1	1	1	3
12		L	2	Hand held	382	4	22	1	1	1	3
13	7	R	2	Hand held	553	6	31	1	1	1	3
14		L	2	GID	334	1	5	1	1	1	3
15	8	R	2	GID	287	1	7	1	1	1	3
16		L	2	Hand held	375	4	18	1	0 (out of the scapho-capital joint)	1	2
17	9	R	3	Hand held	596	5	21	1	1	1	3
18		L	3	GID	320	2	12	1	1	1	3
19	10	R	3	GID	316	1	6	1	1	1	3
20		L	3	Hand held	503	5	23	1	1	0 (out of the radial surface of the scaphoid)	2
21	11	R	3	Hand held	356	4	22	1	1	1	3
22		L	3	GID	291	1	8	1	1	1	3
23	12	R	3	GID	298	1	7	1	1	1	3
24		L	3	Hand held	310	3	14	1	1	1	3
25	13	R	4	Hand held	367	4	21	1	1	1	3
26		L	4	GID	245	1	9	1	1	1	3
27	14	R	4	GID	270	1	7	1	1	1	3
28		L	4	Hand held	256	3	13	1	1	1	3
29	15	R	4	Hand held	301	2	11	1	1	1	3
30		L	4	GID	260	1	9	1	1	1	3
31	16	R	4	GID	275	1	7	1	1	1	3
32		L	4	Hand held	256	3	16	1	1	1	3

In 16 scaphoids, the guidewire were inserted by using the hand held technique and the GID was used for the 16 others. SPS: Segmentary placement score. GPS: Global placement score. GID: Guidewire insertion device.

was performed using a 16-slice multidetector scanner (Sensation 16®, Siemens Medical Solutions, Munich, Germany) to assess wire position. Slice reconstructions and measurements were done using Vitrea 2.2® software (Vital Image, Minneapolis, MN). For each scaphoid, three slices were reconstructed in planes perpendicular to the wire. Each slice was passing through the tubercle (distal third), the waist (middle third), and the middle of the radial surface (proximal third), respectively. To simulate the use of a 2-mm diameter screw, such as Herbert's screw, a circle 3 mm in diameter with the centre at the middle of the guidewire was drawn on each slice. Then, the segmentary placement score (SPS) was determined for each slice, as follows: the score was 0 if part of the circle was outside the scaphoid and 1 if the circle was entirely within the scaphoid. The global placement score (GPS) was calculated as the sum of the SPS values at the distal, middle, and proximal thirds.

Statistical analysis

Data are reported as medians with the interquartile range (IQR). The effect of using the guidewire device on procedure duration, number of placement attempts, and number of image-intensifier shots was assessed using multiple regression models accounting for surgeon experience. Multiple linear regression models accounting for heteroskedasticity and Poisson multiple regression models were built when appropriate. An interaction between surgeon experience and use of the guidewire device was looked for. All analyses were performed using R 2.6.1.[27] All tests were two-sided, with the significance level set at 0.05.

Results

All the results are summarised in Table 1. Overall, median procedure duration was 338 s (IQR, 290–506), median number of attempts was 2 (IQR 1–3), median number of image-intensifier shots was 13 (IQR 7–22), and median GPS was 3 (IQR 3–3). With the hand held technique, median procedure duration was 443 s (IQR 345–603), median number of attempts was 4.5 (IQR 3.8–6), median number of image-intensifier shots was 22 (IQR 18–30), and median GPS was 3 (IQR 2–3). With the GID, median procedure duration was 314 s (IQR 280–324), median number of attempts was 1 (IQR 1–1), median number of image-intensifier shots was 7 (IQR 7–9), and median GPS was 3 (IQR 3–3).

The use of the GID significantly decreased procedure duration ($P < 0.001$), number of attempts ($P < 0.001$), and number of image-intensifier shots ($P < 0.001$). With both techniques, experienced surgeons were significantly faster ($P = 0.0083$) and required significantly fewer attempts ($P = 0.043$) than inexperienced surgeons. An interaction was found between the experience of the surgeons and the use of the GID. The GID had significantly greater effects in decreasing procedure duration ($P = 0.0039$) and number of image-intensifier shots ($P < 0.001$) for inexperienced surgeon than for the experienced surgeons. In contrast, no interaction was found between surgeon experience and number of attempts ($P = 0.32$).

Discussion

Acute nondisplaced fractures of the scaphoid waist are common.[18,20] PSF is an attractive option during which accurate placement of the guidewire is often difficult to achieve. We developed a GID to assist in guidewire placement. Compared to the conventional hand held technique, the device significantly decreased procedure duration, number of image-intensifier shots, and number of placement attempts. Both experienced and inexperienced surgeons obtained these benefits with the GID.

Correct wire placement is a prerequisite to successful PSF of the scaphoid. The technical challenges raised by the placement of the guidewire have prompted the development of guiding systems. In their study describing the use of a double-threaded cannulated screw in 158 patients, Herbert et al. recommended using a jig to facilitate guidewire placement.[16] However, the jig cannot be used for percutaneous procedures. In a cadaver study of eleven scaphoids, Liverneaux et al. found that fluoroscopic navigation facilitated correct percutaneous guidewire placement, compared to the conventional hand held technique.[21] However, fluoroscopic navigation is available only in specialised centres, whereas nondisplaced scaphoid fractures are managed at all centres. The GID we developed allows percutaneous procedures, and does not need any other specific ancillary to be used. The radiotransparent wrist-stabilising device used in this study can be easily replaced by an assistant keeping the hand in the desired position.

In our study, we compared the technique using the GID with the “conventional” hand held technique. Meanwhile, there are two different hand held techniques described in the literature and the choice of the “conventional” technique of reference warrants few justifications. The first hand held technique consists in leaving the patient's hand freely movable under the beam of the image intensifier.[4,15] The second hand held technique uses chinese finger traps to suspend the wrist which remains free to rotate under the beam of the image intensifier.[13,14] As Liverneaux et al.[21] we chose the first one as the hand held reference technique because it is the one we usually perform in our department and because it is probably the technique used by most of the surgeons.

Fluoroscopic guidance exposes the patient and surgeons to ionising radiations, which can induce radiodermatitis and skin cancer after several decades.[22,30] Dose reduction during fluoroscopy-guided interventions is challenging.[17] Some surgeons use mini C-arm which allow minimal radiation exposure[12,29] but that kind of device remains restricted to a few number of centres whereas most of orthopaedic surgeons in the world still use conventional image intensifiers. For Shoaib et al., even if the mini C-arm caused statistically less radiation to the surgeon, there was no statistically significant difference in the radiation exposure to the patient.[29] Moreover, even when using a mini C-arm, there is a substantial amount of measurable radiation exposure for the structures in line with the imaging beam.[12] Thus, radiation exposure is unavoidable when performing PSF of the scaphoid but the dose must be kept as small as possible. This was one of the reasons why we developed the GID. A cadaver study showed that fluoroscopic navigation was associated with a four-fold decrease in radiation exposure, compared to the conventional wire-placement method[21] but nowadays, such a technology remains limited to a few centres. Although the radiation dose varies with the type of image intensifier, it is consistently proportional to the number of shots. That is why we decided to use the number of image-intensifier shots to estimate the amount of radiations. It would have been tempting to use a dosimeter placed into the surgeon's gloves and on the specimen's hand in order to measure the delivered dose more precisely. Nevertheless, the measured data would have been very dependant on the positioning (palmar or dorsal side of the hands) and orientation of the dosimeters and it would have been a potential source of confusion in data interpretation. In our study, compared to the conventional hand held technique, the use of the GID was associated with an about 3-fold decrease in the number of image-intensifier shots, and therefore in radiation exposure. In addition, the shorter procedure duration and smaller number of attempts indicate facilitation of wire placement with the GID.

Our study has several limitations. First, results obtained in cadavers may not reflect in vivo results. However, the beneficial effects of the device may be even larger in everyday practice, when the restricted room available in the operating theater, time constraints, stress, and fatigue may provide additional opportunities for the device to facilitate wire placement. Second, brief explanations about the device were given orally to the surgeons before the study. Nonetheless, no attempts were performed with the GID before the study (except by the first author who developed the device) and all cases including the first one were included in the analysis. Therefore, use of the GID seems easy to learn. Second, our study does not demonstrate that the GID is associated with improved clinical outcomes. However, the decrease in radiation exposure is an important benefit. Furthermore, easier wire placement may lead surgeons to use PSF instead of prolonged cast immobilisation for treating nondisplaced scaphoid fractures, which can be expected to accelerate time to work resumption and time to recovery of wrist function. For all these reasons, a clinical study already started assessing this GID in vivo.

Conclusion

This cadaver study showed that the GID decreased the time and radiation exposure needed to achieve correct percutaneous guidewire placement in the scaphoid, compared to the conventional hand held technique. These benefits were obtained both by experienced and by inexperienced surgeons. Clinical studies of the device are warranted.

Conflict of interest

None of the authors received fundings, grants, or in-kind in support of the research or the preparation of the manuscript.

None of the authors have association or financial involvement with any organisation or commercial entity having a financial interest in or financial conflict with the subject matter or research presented in the manuscript.

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